(e) Doppler effect; Doppler shift of electromagnetic radiation

(f) Doppler equation $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$ for a source of electromagnetic radiation moving relative to an observer

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

The Doppler effect

STARTER: Try this question on parallax.
Ex: Why is there a limit to the parallax method? what are the alternatives?

0:00:00

The star Arcturus has a parallax of 0.09 arc seconds. How far is it from the Earth? [1]
The parallax technique can be used successfully to determine the distances of stars to a maximum distance of 100 pc. Calculate the parallax, in arc seconds, for this maximum distance. [1]

a $d = \frac{1}{p} = \frac{1}{0.09} = 11.1 \approx 11 \text{ pc}$

b $p = \frac{1}{d} = \frac{1}{100} = 0.01 \text{ arc seconds}$

Sep 29-15:54

(e) Doppler effect; Doppler shift of electromagnetic radiation

(f) Doppler equation $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$ for a source of electromagnetic radiation moving relative to an observer

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

The Doppler effect $d = \frac{1}{p}$

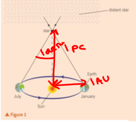
STARTER: Try this question on parallax.
Ex: Why is there a limit to the parallax method? what are the alternatives?

0:00:00

Practice questions

1 a Calculate the distance of 1 light-year (ly) in metres. *(1 mark)*

b Figure 1 shows an incomplete diagram drawn by a student to show what is meant by a distance of 1 parsec (pc).



▲ Figure 1

Complete a copy of Figure 1 by showing the distances of 1 pc and 1 AU, and the parallax angle of 1 second of arc (1″). *(1 mark)*

c A recent supernova, SN2011fe, in the Pinwheel galaxy, M101, released 10^{44} J of energy. The supernova is 2.1×10^7 ly away.

(i) Calculate the distance of this supernova in pc.
$1 \text{ pc} = 3.1 \times 10^{16} \text{ m}$ *(2 marks)*

(ii) Our Sun radiates energy at a rate of 4×10^{26} W. Estimate the time in years that it would take the Sun to release the same energy as the supernova SN2011fe. *(2 marks)*

d One of the possible remnants of a supernova event is a black hole. State **two** properties of a black hole. *(2 marks)*

Jun 2013 G485

Question	Answer	Marks
1 (a)	distance = $3.0 \times 10^8 \times 3.16 \times 10^7$ distance = 9.48×10^{15} m	1
1 (b)	Correct labelling of 1 pc, 1 AU and 1 ″.	1
1 (c) (i)	distance = $9.5 \times 10^{15} \times 2.1 \times 10^7$ m = 2.0×10^{23} m distance (in pc) = $\frac{2.0 \times 10^{23}}{3.1 \times 10^{16}}$ distance = 6.4×10^6 pc	1 1
1 (c) (ii)	time = $\frac{10^{44}}{4 \times 10^{26}}$ s time = 2.5×10^{17} s time = $\frac{2.5 \times 10^{17}}{3.16 \times 10^7}$ time = 7.9×10^9 years	1 1
1 (d)	Any one from: • Very dense / infinite density / very small / singularity. Any one from: • Very strong gravitational field therefore light cannot escape from it / curves space / slows down time / emits Hawking radiation.	1 1

Sep 29-15:54

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

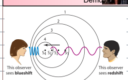
Activity: What is the doppler effect?

Check you checklist - what are we doing today?

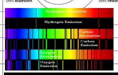
doppler BBT

Extension: How does it relate to study of cosmology?

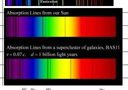
Demo



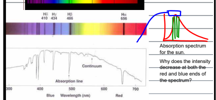
Why are we more likely to experience **redshift** when observing galaxies?



How can you determine the composition of different stars?

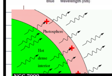


What information can be gained about BAS11 super cluster using the light that creates the absorption spectra?



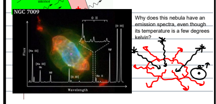
Absorption spectrum for the sun.

Why does the intensity decrease at both the red and blue ends of the spectrum?



Remind us what causes absorption spectra?

Refer to electrons in your answer



Why does this nebula have an emission spectra, even though its temperature is a few degrees kelvin?

Sep 29-15:54

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

Activity.

0:00:00

1. Define the Doppler effect. Use a labelled diagram to show this effect.

	Red Shift	Blue shift
Relative motion	away from observer	towards observer
Change in λ	increase	decrease
Reason for changing λ	Wave fronts are stretched out by relative motion away	Wave front are compressed by relative motion towards
Change in f	decrease	decrease
Observation that leads to determination of shift type	Viewing absorption spectrum. Absorption lines shifted towards the red end of the spectrum (in comparison to the same element's absorption lines in the lab.	Viewing absorption spectrum. Absorption lines shifted towards the blue end of the spectrum (in comparison to the same element's absorption lines in the lab.

Ex: For last row, consider the difficulties in determining shift, if the colour of a star is determined by temperature

Ex: How can you calculate the speed of recession of a star?

Sep 29-15:54

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

Doppler equation

$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

λ - Source wavelength / m
Δλ - change in wavelength / m
f - Source frequency / Hz
Δf - Change in frequency / Hz
v - Relative velocity / m/s
c - Speed of light in a vacuum / m/s

The equation show that the faster the relative motion the greater the observed change in wavelength.

Worked example: Speed of a galaxy

In the laboratory an absorption line of hydrogen is observed at a wavelength of 656.4 nm. In a distant galaxy the same absorption line is observed at 658.1 nm. Calculate the speed of the galaxy and state whether it is moving towards or away from the Earth.

Worked example: Speed of a galaxy

In the laboratory an absorption line of hydrogen is observed at a wavelength of 656.4 nm. In a distant galaxy the same absorption line is observed at 658.1 nm. Calculate the speed of the galaxy and state whether it is moving towards or away from the Earth.

Step 1: Calculate the change in the wavelength

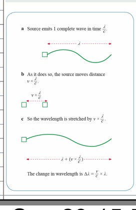
$\Delta\lambda = 658.1 - 656.4 = 1.7 \text{ nm}$

The wavelength observed from the galaxy is longer than the wavelength in the laboratory, so the galaxy must be receding. The spectral line has been red-shifted.

Step 2: The Doppler equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ can be rearranged to give $\frac{c\Delta\lambda}{\lambda} = v$.

Therefore

$v = \frac{c\Delta\lambda}{\lambda} = \frac{3.00 \times 10^8 \times 1.7 \times 10^{-9}}{656.4 \times 10^{-9}} = 7.76... \times 10^5 \text{ m s}^{-1} \approx 780 \text{ km s}^{-1}$ (2 s.f.)



Sep 29-15:54

(6) M - Define the Doppler effect
(7) S - Explain the Doppler shift of electromagnetic radiation
(8) C - Apply the Doppler equation for moving sources of electromagnetic radiation.

Activity: Complete the summary questions on the Doppler effect.

Ex: Try the stretch and challenge sheet.

Plenary:

In the laboratory, a particular spectral line from hydrogen atoms has a wavelength of 2.1 cm. Calculate the change in the wavelength of the same spectral line from hydrogen atoms of a galaxy receding from the Earth at a speed of 8000 km s^{-1} [3]

Answer

$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ [1]

$\Delta\lambda = \frac{v}{c} \times \lambda = \frac{8000 \times 10^3}{3.0 \times 10^8} \times 2.1 \text{ cm}$ [1]

$\Delta\lambda = 0.056 \text{ cm}$ [1]

Sep 29-15:54